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AD-A215 154

Bibliography of In-House and Contract Reports, Supplement 16

Annemarie Black
E. James Books
Karen Carroll

October 1989

U.S. Army Corps of Engineers
Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060-5546

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This is Supplement 16 to the (ETL) *Bibliography of In-House and Contract Reports.* This supplement provides author and title indexes, abstracts, and AD numbers for the 1987, 1988 and 1989 additions to the continuing bibliography. It also contains a complete title index designed to be used in conjunction with the 16 published bibliographies and refers to them by year and number.

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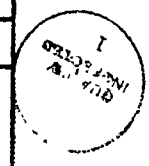

PREFACE

This is Supplement 16 to the report titled, "Bibliography of In-House and Contract Reports" AD-877 653L; Supplement 1, AD-890 066L; Supplement 2, AD-905 548L; Supplement 3, AD-B005 275L; Supplement 4, AD-B010 642L; Supplement 5, AD-B019 966L; Supplement 6, AD-055 468; Supplement 7, AD-A068 744; Supplement 8, AD-A084 111; Supplement 9, AD-A099 803; Supplement 10, AD-A113 006; Supplement 11, AD-A128 400; Supplement 12, AD-A141 778; Supplement 13, AD-A160 607; Supplement 14, AD-A173 750; and Supplement 15, AD-A195 953. It is a continuing bibliography of reports prepared by and for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia. This bibliography includes reports that were published from 1 January 1988 through 30 September 1989.

Reports with AD numbers can be purchased by Department of Defense agencies from the Defense Technical Information Center; other agencies and individuals can purchase copies from the National Technical Information Service, Springfield, Virginia 22161-2171. Reports with a "B" in the AD number are limited in distribution to U.S. Government agencies unless permission for release is granted from the controlling office. Reports are available on an interlibrary loan from the Scientific and Technical Information Center, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060-5546.

Colonel David F. Maune, EN, was Commander and Director, and Mr. Walter E. Boge was Technical Director of the Engineer Topographic Laboratories during the report preparation.

ETL-0478 AD-A203 257

COMPUTER STRATEGY FOR DETECTING LINE FEATURES ON SIMULATED BINARY ARRAYS IN SUPPORT OF RADAR FEATURE EXTRACTION
November 1988

Frederick W. Rohde

Keywords: Radar Image Analysis, Terrain Feature Extraction, Terrain Analysis

Line search techniques for linear features in digital radar images are developed and described. It is shown that the search techniques can be represented by codes. The codes determine the major directions of search and the removal of side branches. The testbed that is necessary to investigate and test the search techniques is described.

ETL-0488 AD-A208 271

PARALLEL VISION ALGORITHMS
FIRST ANNUAL TECHNICAL REPORT
October 1987

Hussein A. H. Ibrahim, Editor
John R. Kender
Lisa G. Brown

Columbia University

DACA76-86-C-0024

Keywords: Computer Vision, Artificial Intelligence, Image Understanding, Multi-Resolution, Stereo, Texture, Strategy Computing

The "Parallel Vision Algorithms" annual report covers the project activities during the period from October 1, 1986, through September 30, 1987. The objective of this project is to develop and implement, on highly parallel computers, vision algorithms that combine stereo, texture, and multi-resolution techniques for determining local surface orientation and depth. Such algorithms will immediately serve as front-ends for autonomous land vehicle navigation systems. During the first year of the project, efforts have concentrated on two fronts. First, developing and testing the parallel programming environment that will be used to develop, implement and test our parallel vision algorithms. Second, developing and testing multi-resolution stereo, and texture algorithms. This report describes the status and progress on these two fronts. We describe first the programming environment developed, and mapping scheme that allows efficient use of the connection machine for pyramid (multi-resolution) algorithms. Second, we present algorithms and test results for multi-resolution stereo, and texture algorithms. Also the initial results of the starting efforts of integrating stereo and texture algorithms are presented.

ETL-0489 AD-A190 345

AN EXPERT VISION SYSTEM FOR AUTONOMOUS LAND VEHICLE ROAD FOLLOWING
January 1988

Sven J. Dickinson
Larry S. Davis

University of Maryland DACA76-84-C-0004

Keywords: Image Understanding, Vision-Based Navigation, Computer Vision Processing, Structured Blackboard

A production system model of problem solving is applied to the design of a vision system by which an autonomous land vehicle (ALV) navigates roads. The ALV vision task consists of hypothesizing objects in a scene model and verifying these hypotheses using the vehicle's sensors. Object hypothesis generation is based on the local navigation task, an *a priori* road map, and the contents of the scene model. Verification of an object hypothesis involves directing the sensors toward the expected location of the object, collecting evidence in support of the object, and reasoning about the evidence. Constructing the scene model consists of building a semantic network of object frames exhibiting component, spatial, and inheritance relationships. The control structure is provided by a set of communicating production systems implementing a structured blackboard; each production system contains rules for defining the attributes of a particular class of object frame. The combination of production system and object oriented programming techniques results in a flexible control structure able to accommodate new object classes, reasoning strategies, vehicle sensors, and image analysis techniques.

ETL-0490 AD-A190 346

BUILDING A 3-D WORLD MODEL FOR A MOBILE ROBOT FROM SENSORY DATA
January 1988

Minoru Asada

University of Maryland DACA76-84-C-0004

Keywords: Autonomous Land Vehicle, World Model, Sensor Map, Height Map, Global Map, Path Planning, Range Data

This paper presents a method for building a 3-D world model for a mobile robot from sensory data. The 3-D world model consists of three kinds of maps: a sensor map, a local map and a global map. A range image (sensor map) is transformed to a height map (local map) with respect to a mobile robot. First, the height map is segmented into four categories (unexplored, occluded, traversable, and obstacle regions) for obstacle detection and path planning. Next, obstacle regions are classified into artificial objects (buildings, cars, road signs, etc.) or natural objects (trees, bushes, etc.) using both the height image and video image. One drawback of the height map — the recovery of vertical planes — is overcome by the utilization of multiple height maps which include the maximum and minimum height of each point, and the number of points in the range image mapped into one point in the height map. The multiple height map is useful not only for finding vertical planes in the height map but also for segmentation of the video image. Finally, the height maps are integrated into a global map by matching geometrical properties and updating region labels. The method is tested on a model including many objects, such as trees, buildings, cars, and so on.

ETL-0491 AD-A192 139

PRODUCTION OF DENSE RANGE IMAGES WITH THE CVL LIGHT-STRIPE RANGE SCANNER
January 1988

Daniel DeMenthon
Tharakesh Siddalingaiah
Larry S. Davis

University of Maryland DACA76-84-C-0004

Keywords: Range Scanner, Computer Vision, Range Images, Light-Stripe Scanner

This report describes a system able to produce 512 x 512 range images of model scenes in the laboratory. This ranging instrument, which comprises a light-emitting slit, a cylindrical lens, a step-motor controlled mirror and a CCD camera, is compact enough to be mounted on the tool plate of a robot arm. The light source itself is mounted away from this structure, and the light is brought to the slit by a flexible fiberoptic light guide. The robot arm's motion can be controlled by inputs from the range scanner, for simulation of autonomous vehicles equipped with rangers. This system is programmed to produce range images which are comparable in many respects to range images produced by laser range scanners. With this similitude of formats, software for edge detection, object recognition, dynamic path planning or data fusion with video images can be developed on range images produced by this laboratory equipment and can be easily ported to laser ranging systems.

ETL-0492 AD-A192 990

EXPERT SYSTEM FOR MINEFIELD SITE PREDICTION (PHASE I) FIRST YEAR REPORT
February 1988

Michael Dillencourt
Jonathan W. Doughty
Anne L. Downs

PAR Government Systems Corporation DACA72-86-C-0017

Keywords: Expert System, Minefield Site Prediction, Quadtree, Terrain Analysis

The software design of the prototype Minefield Site Prediction Expert Systems (MSPES) is described. The ultimate goal of the system is to emulate the role of a terrain analyst in predicting likely mine sites. The major components of the system are the inference system, the geographic information system, and the user interface. The inference system is driven by a goal-directed backward chaining mechanism. The geographic information system is based on quadtrees. The user interface is menu-driven, and is based on an object-oriented graphics package.

The report describes the implementation of the prototype system. It also contains recommendations for the operational system, based on an evaluation of the prototype system. Descriptions of data format conversion capabilities, a detailed description of the geographic processing algorithms, and a complete listing of the rulebase are included as appendices.

ETL-0493 AD-B120 373L

AN APPROACH TO MODEL FORMATION BASED ON FORMAL GEOMETRIC REASONING
March 1988

Deepak Kapur
Joseph L. Mundy

General Electric Company DACA76-86-C-0007

Keywords: Model Matching, Image Understanding, Range Sensor, Geometric Reasoning

Methods for model matching and model formation are developed in the context of a model-based image understanding system. A method using a pair of vertices and associated edges for determining the correct match between an object model and an unsupervised segmentation of an image data into two dimensional edges and vertices is outlined.

Two approaches towards generation of models for model matching are discussed. The first approach involves the use of a range sensor which uses triangulation to determine a set of three-dimensional structures of an object. This approach has been successful in generating a polyhedral object which can be used for model matching. Efforts are under way to apply the approach to military vehicles. The second approach involves the use of geometric and algebraic reasoning methods to generate a set of constraints on the geometric and topological structure of an object from its image. These constraints are subsequently used as a model for matching against another image (called the view consistency problem). The effort so far has been to develop and experiment with techniques for reasoning about geometry relationships. A geometric reasoning system, GEometer, has been developed which has been used to prove hundreds of plane geometry theorems. GEometer has also been extended to solve the view consistency problem of ideal polyhedral objects.

ETL-0494 AD-A193 375

A SIMPLE COMPUTER DATABASE SYSTEM FOR UNIX
March 1988

Michael M. McDonnell

Keywords: UNIX, String, Database, Inventory, Rolodex, Computer Program

This is a computer program that allows users to maintain and access a file containing addresses, inventory items, or other units of text information grouped in blocks separated by blank lines. Any string within a file may be used to find and print the block(s) of text containing the string. A file is created, maintained, and accessed by a group of UNIX programs which have been designed for speed and simplicity. Besides being useful in themselves, these programs illustrate cooperative use of C programs and shell command files. A history of the development will also be given since this is of general interest to programmers.

This program uses standard UNIX techniques, except for the Boyer-Moore string matching algorithm. It offers a simple and extensible approach to the type of database represented by the rolodex file found in many offices. This simple flat-file database has proven valuable as a way of maintaining and accessing an inventory file and an address file. The data file is a plain text file containing no control characters aside from new lines. The file is therefore easy to create and maintain using ordinary text editors, though a program is provided to facilitate item entry for users. On an unloaded VAX 780 it takes about 1.5 seconds to search a data file of 150,000 characters. On a system which is about 10 users, this time is about 3 seconds.

ETL-0495 AD-A203 947

PARALLEL ALGORITHMS FOR COMPUTER VISION
SECOND YEAR REPORT
March 1988

Tomaso Poggio
James Little

Massachusetts Institute of Technology DACA76-85-C-0010

Keywords: Computer Vision, Parallel Algorithms & Architectures

Much of our work during the past year has focused on building our Vision Machine system. The Vision Machine is a testbed for our research on parallel vision algorithms and their integration. The system consists of an input device — a movable two camera Eye-Head system with six degrees of freedom — and the 16K Connection Machine (CM-1). We have concentrated on implementing and testing early vision algorithms, and on developing new sophisticated techniques for their integration. The output of the integration stage will be used for navigation and recognition tasks.

From August 31, 1986 to August 31, 1987, we have been using the Connection Machine delivered on July 31, 1986 by Thinking Machines Corporation (TMC). We have developed and tested a substantial body of vision software on the machine. We have also nearly completed, well ahead of schedule, the development of an integrated Vision Machine that includes several early vision algorithms, and the integration stage of middle vision. As outlined in our original proposal, we have begun to explore parallel algorithms at the higher level of recognition. We have also studied the performance of alternative, nonconventional architectures for navigation, and worked on the difficult issue of alternative parallel languages for the Connection Machine, in addition to *LISP and C*. The body of this report gives an overview of the results of our research during the second twelve months of funding. Details can be found in the report.

ETL-0497 AD-A203 688

LINEAR FEATURE EXTRACTION FROM RADAR IMAGERY: SBIR PHASE II, OPTION I
April 1988

Gary D. Connor
David L. Milgram
Daryl T. Lawton
Christopher C. McConnell

Advanced Decision Systems DACA72-86-C-0004

Keywords: SAR, Feature Extraction, Edge Detection, Terrain Analysis, Image Understanding

The goal of this effort is to develop and demonstrate prototype processing capabilities for a knowledge-based system to automatically extract and analyze linear features from synthetic aperture radar (SAR) imagery. This effort constitutes Phase II funding through the Defense Small Business Innovative Research (SBIR) Program. Previous work examined the feasibility of and technology issues involved in the development of an automated linear feature extraction system. This Option I Final Report documents this examination and the technologies involved in automating this image understanding task. In particular, it reports on a major software delivery containing an image processing algorithmic base, a "perceptual structures" manipulation package, a preliminary hypothesis management framework and an enhanced user interface.

ETL-0499 AD-A203 816

THE IMAGE UNDERSTANDING ARCHITECTURE PROJECT FIRST ANNUAL REPORT April 1988

Charles C. Weems
Steven P. Levitan
Allen R. Hanson
Edward M. Riseman
David B. Shu
J. Gregory Nash
James Burrill
Michael Rudenko

University of Massachusetts

DACA76-86-C-0015

Keywords: Image Understanding Architecture, Knowledge-Based Vision, Real-Time Computer Vision, Software Simulator, Parallel Processor

This report presents the results of the Image Understanding Architecture (IUA) project for the first year of its two-year contract period. The purpose of the IUA project is to design and construct a next-generation parallel processor that specifically addresses the needs of real-time computer vision applications.

The current effort involves the construction of a proof-of-concept, 1/64th scale prototype IUA system (hardware and software) that will serve as the basis of research leading to the design and construction of the next generation IUA system. The work is being performed jointly by the University of Massachusetts at Amherst, and Hughes Research Laboratories in Malibu.

Included in this report are a summary of accomplishments during the first year, an overview of the IUA design, a collection of algorithms, a discussion of a vision processing scenario as it is expected to take place on the IUA, a summary of the performance figures for the IUA on the DARPA IU Benchmark Exercise, a detailed description of the architecture of the bottom level of the IUA, documentation for the IUA software simulators, and a report of the hardware design efforts at Hughes.

ETL-0500 AD-A195 953

BIBLIOGRAPHY OF IN-HOUSE AND CONTRACT REPORTS, SUPPLEMENT 15 April 1988

Annemarie Black
E. James Books
Karen Carroll

Keywords: Bibliography, Scientific Reports

This is Supplement 15 to the ETL *Bibliography of In-House and Contract Reports*. This supplement provides author and title indexes, abstracts, and AD numbers for the 1986 and 1987 additions to the continuing bibliography. It also contains a complete title index designed to be used in conjunction with the 15 published bibliographies and refers to them by year and number. AD-877 653L (1970); AD-890 066L (1971); AD-905 548L (1972); AD-B005 275L (1975); AD-B010 642L (1976); AD-B019 966L (1977); AD-A055 468 (1978); AD-A068 744 (1979); AD-A084 111 (1980); AD-A099 803 (1981); AD-A113 006 (1982); AD-A128 400 (1983); AD-A141 778 (1984); AD-A173 750 (1986).

ETL-0501 AD-B132 062L

ANALYSIS AND TEST RESULTS OF A GYROCOMPASS WITH REDUCED SUSCEPTIBILITY TO SHOCK, VIBRATION, AND MOTION
May 1988

Barbara S. Gryglaszewski
R. J. Craig

Incosym, Inc.

DACA72-85-C-0003

Keywords: Earth Rate, North, Gyrocompass, Azimuth, Axis, Angular Rate, Heading, Align, Inclination, Rotate, Milliradian, Time Constant, Bias, Gyro, Accelerometer

Analysis, fabrication, and testing was performed to determine operating performance in severe dynamic environments (angular rotations and translocational accelerations) of the North finding system known as the Azimuth and Inclination Measuring System (AIMS). Tests were performed in both the laboratory and a test vehicle. Test data showed that the AIMS system could find North to an accuracy of approximately 2 milliradians under severe dynamic conditions in a period of 60 to 120 seconds over temperature range from -35 degrees Centigrade to 50 degrees Centigrade. The dynamic environments included angular translational vibrations as high as 1 g over frequency range of 1 to 6 Hz.

Additional tests performed in a test van exposed to heavy wind gusts with personnel inside and engine running showed accuracy of 2.5 milliradians with total reaction time equal to 60 seconds.

ETL-0502 AD-A200 291

IMPROVING CLASSIFICATION ACCURACY OF RADAR IMAGES USING A MULTIPLE-STAGE CLASSIFIER
September 1988

Neil D. Fox
P. F. Chen

Keywords: Radar Image Feature Extraction, Texture, Histogram, Classification, Pattern Recognition, Edge Operators

A simple method was introduced to classify radar image samples repeatedly for achieving a higher accuracy than by using a single-stage classifier. A Sobel edge operator was applied between the stages of classification to enhance the difference in texture between categories of radar image samples, thus reducing the overlap of image categories.

ETL-0503 AD-A201 023

AN EMPIRICAL SURFACE TEMPERATURE MODEL
September 1988

Alan E. Krusinger

Keywords: Surface Temperature, Thermal Infrared, Empirical Model, Backgrounds, Type-Days, Background Clutter, ATR, Automatic Target Recognition, Meteorological Variables, Modeling, Diurnal Temperature, Composite Days, Curve Fitting

Based on long-term radiometric, temperature, and meteorological measurements, made at instrumented test sites, the U.S. Army Engineer Topographic Laboratories (USAETL) has developed an empirical surface temperature prediction model. The model has simple inputs, with no measurements, for use by the field Army. The model uses analogous climates and type-days, or composite days, of relatively unique weather conditions. Model inputs of climate, season, sky cover, and surface soil wetness produce diurnal temperature curves for various backgrounds, for each type-day. The temperate climate, summer season model is presented in this report.

ETL-0504 AD-A201 171

COMPUTER GENERATION OF FRACTAL TERRAINS
September 1988

Eugene A. Margerum
Anne Werkheiser

Keywords: Fractals, LISP, Terrain, Artificial Landscapes, Simulation, Computer Graphics

The use of fractals for the generation of artificial terrains is presented. An introduction to the relevant basic properties of fractals is given and a method for the generation of artificial fractal landscapes is described. The algorithm has been used to develop a LISP computer program for synthesizing topographic surfaces. Examples of the resulting structures are given in the form of a series of profiled surfaces representing landscapes of varying fractal dimension and varying vertical dilation. The LISP computer programs are also given and described.

ETL-0505 AD-A200 157

A BIBLIOGRAPHY ON THE CHEMICAL WEATHERING OF GRANITIC ROCKS
September 1988

Judy Ehlen, USAETL
A. J. W. Gerrard, School of Geography, University of Birmingham, England

Keywords: Chemical Weathering, Granitic Rocks, Geomorphology, Soils, Geology

This bibliography lists many of the papers in the international published geological, geomorphological and soils literature that discuss the chemical weathering of rocks often considered "non-soluble." Emphasis is placed on granitic rocks.

ETL-0506 AD-B132 495L

AUTONOMOUS LAND VEHICLE (ALV) PROGRAM — PHASE I FINAL REPORT May 1988

Rainer Koenig, Editor

Martin Marietta Information and Communications Systems DACA76-84-C-0005

Keywords: Autonomous Land Vehicle, Unmanned Vehicles, Robotics, Artificial Intelligence, Image Understanding, Computer Vision Processing

During Phase I of the ALV prc;ram, we went through three generations of requirements definition, hardware and software design, system integration and testing, culminating in increasingly more difficult system demonstrations. These demonstrations took place in May 1985 (1 km of road following at 3 km/hr); in May 1986 (4 km of road following at speeds up to 10 km/hr) and, in November 1987 (4.2 km of road following at speeds up to 20 km/hr and averaging a speed of 14 km/hr while avoiding obstacles on the road). In addition to these demonstrations, the ALV program has supported the DARPA Strategic Computing (SC) community in the areas of image processing and understanding, advanced parallel processing architectures, reasoning (planning, navigating, piloting), and sensor integration. Technology transfers took place in both directions, involving various corporations such as Hughes, General Dynamics, and FMC, as well as several universities, such as Carnegie-Mellon University (CMU), the University of Maryland, the University of Massachusetts, Stanford University, and the Massachusetts Institute of Technology.

ETL-0507 AD-B129 663L

KNOWLEDGE-BASED VISION TECHNIQUES FOR THE AUTONOMOUS LAND VEHICLE (ALV) PROGRAM SECOND ANNUAL REPORT June 1988

Martin A. Fischler
Robert C. Bolles

SRI International DACA76-85-C-0004

Keywords: Knowledge Representation, 3-D Descriptions, Mission Planning, Computer Vision

The goal of this research is to develop techniques for automatically acquiring and representing knowledge about complex cultural and natural environments for such purposes as intelligence analysis, planning, navigation, and manipulation. Our research strategy is to (1) develop representations and techniques for storing (or incrementally learning) semantic and geographic information about a specific geographic area to permit both mission planning and knowledge-based interpretation of sensed data, (2) develop representations for natural and man-made objects, (3) develop techniques to predict distinctive features of these objects that can be used to identify them, and (4) develop techniques for building three-dimensional descriptions of an environment from data gathered by range or intensity sensors moving through this environment. In this report we describe our progress and plans in these areas.

ETL-0508 AD-A203 689

DEVELOPMENT OF AN INTEGRATED MOBILE ROBOT SYSTEM AT CMU JUNE 1987 ANNUAL REPORT
July 1988

Steve Shafer
William Whittaker

Carnegie-Mellon University DACA76-86-C-0019

Keywords: Strategic Computing, Machine Vision, Autonomous Land Vehicle

This report describes progress in development of an integrated mobile robot system at the Carnegie-Mellon Robotics Institute from July 1986 to June 1987. This research was sponsored by DARPA as part of the Strategic Computing Vision Program.

Our program includes a broad agenda of research in the development of mobile robot vehicles. In the year covered by this report, we addressed two major areas in vehicle development (NAVLAB vehicle and Robot control system) and two major areas in robot architecture development (CODGER blackboard and Navigation architecture). We built the NAVLAB mobile robot vehicle by outfitting a commercial truck chassis with computer-controlled drive and steering controls and a set of on-board computer workstations. The NAVLAB serves as a mobile navigation laboratory that allows researchers to interact intensively with the system during testing and execution. We also developed a real-time controller system for the NAVLAB using a collection of coordinated processors and software. The CODGER blackboard system incorporates substantial features for geometric reasoning and task synchronization that have not been incorporated in blackboards before. We also developed the Driving Pipeline architecture for coordinating road following, obstacle avoidance, and vehicle motion control. This hardware and software combination is the basis for the New Generation System (NGS) for robot vision and navigation, which will tie together existing and emerging technologies.

ETL-0509 AD-A203 712

VISION-BASED NAVIGATION FOR AUTONOMOUS GROUND VEHICLES FIRST ANNUAL REPORT
July 1988

Larry S. Davis

University of Maryland DACA76-84-C-0004

Keywords: Autonomous Navigation, Road Following, Computer Vision

This is the first annual report for ETL contract DACA76-84-C-0004. Our activities on the project principally involved building an experimental facility for performing research in vision for autonomous navigation of ground vehicles and developing a computational framework for constructing visual navigation systems.

ETL-0510 AD-A203 309

A PROGRAMMING ENVIRONMENT FOR PARALLEL VISION ALGORITHMS
Third Annual Report
July 1988

Christopher Brown

University of Rochester

DACA76-85-C-0001

Keywords: Parallel Processors, Computer Vision, Butterfly Computer

During the third year of the award period, the Computer Science Department of the University of Rochester concentrated on (1) operating systems, debugging support, and performance monitoring for parallel computation, (2) systems utilities for large-scale MIMD (multiple instruction stream, multiple data stream) computation, and (3) applications in active vision. This research produced internal and external reports, as well as some exportable code and several demonstration systems. Implementation of Psyche, a new operating system for large shared-memory non-uniform memory access time computers has begun. The BBN Butterfly Parallel Processor was not applied to low-level vision; instead a parallel-pipelined special-purpose device, the Datacube MaxVideo system, was integrated into the laboratory environment. The vision laboratory was also enhanced by a robot arm that positions and moves the three degree-of-freedom, two-camera robot head. Work was begun on an integrated, heterogeneously parallel system using the Butterfly, the MaxVideo, and other local computers to do complex visuo-motor tasks.

ETL-0511 AD-B129 618L

AUTONOMOUS LAND VEHICLE (ALV) PLANNING AND NAVIGATION SYSTEM
SECOND ANNUAL REPORT
July 1988

D. Keirsey, D. Payton, J. Rosenblatt, D. Tseng, V. Wong

Hughes Research Laboratories

DACA76-85-C-0017

Keywords: Autonomous Vehicles, Planning, Navigation, Cross-Country

This report details the history-making cross-country navigation experiments performed on the Autonomous Land Vehicle (ALV) and describe in detail the planning software used in these experiments. An overview of the software architecture and the systems development methodology will be also presented.

ETL-0512 AD-B132 948L

KNOWLEDGE-BASED VISION TECHNIQUES FOR THE AUTONOMOUS LAND VEHICLE (ALV) PROGRAM THIRD ANNUAL REPORT July 1988

Martin A. Fischler
Robert C. Bolles

SRI International DACA76-85-C-0004

Keywords: Knowledge Representation, 3-D Descriptions, Mission Planning, Computer Vision

The goal of this research is to develop techniques for representing knowledge about complex cultural and natural environments so that a computer vision system can successfully recognize key navigational features, such as roads, bushes, cliffs, and buildings. Our research strategy is to (1) develop representations and techniques for storing (or incrementally learning) semantic and geographic information about a specific geographic area to permit both mission planning and knowledge-based interpretation of sensed data, (2) develop representations for natural and man-made objects, (3) develop techniques to predict distinctive features of these objects that can be used to identify them, and (4) develop techniques for building three-dimensional descriptions of an environment from data gathered by range or intensity sensors moving through this environment. In this report we describe our progress and plans in these areas.

ETL-0513 AD-A203 361

PARALLEL VISION ALGORITHM DESIGN AND IMPLEMENTATION 1987 END OF YEAR REPORT August 1988

Takeo Kanade
Jon Adrian Webb

Carnegie-Mellon University DACA76-85-C-0002

Keywords: Computer Vision, Systolic Processors, Benchmarks, Programming Languages, Parallel Computers, Systolic Warp, Image Processing

Progress on the Parallel Vision project is reported. Three major accomplishments are noted: the development of the Apply language, the WEB library, and benchmarks of Warp for the DARPA image understanding architecture comparisons. The Apply language development included a description of the language and its implementation on warp, the Sun, and the Hughes HBA, together with benchmark comparisons of these very different architectures. The WEB library includes over 100 routines; included in this report are performance numbers of these routines on the CMU Warp machine. Finally, a detailed analysis of the Warp routines implemented for the DARPA Image Understanding benchmarks is given.

ETL-0514 AD-A203 946

1987 YEAR END REPORT FOR ROAD FOLLOWING AT CARNEGIE-MELLON
August 1988

Charles E. Thorpe
Takeo Kanade

Carnegie-Mellon University DACA76-85-C-0003

Keywords: Road Following, Range Data Interpretation, Expert Systems for Image Interpretation, Car Recognition, Geometric Camera Calibration

This report describes progress in vision and navigation for outdoor mobile robots at the Carnegie-Mellon Robotics Institute during 1987. This research was primarily sponsored by the Defense Advanced Research Projects Agency (DARPA) as part of the Strategic Computing Initiative. Portions of this research were also partially supported by the National Science Foundation and Digital Equipment Corporation.

We are pursuing a broad range of perception research for guiding outdoor autonomous vehicles. In 1987 we concentrated on five areas: 1. Road following, 2. Range data interpretation, 3. Expert systems for image interpretation, 4. Car recognition, and 5. Geometric camera calibration.

This report begins with an introduction, chronology, and lists of personnel and publications. It also includes papers describing each of the research areas.

ETL-0516 AD-A204 167

DYNAMIC IMAGE INTERPRETATION FOR AUTONOMOUS VEHICLE NAVIGATION
1987 END OF YEAR TECHNICAL REPORT
September 1988

Edward M. Riseman
Allen R. Hanson

University of Massachusetts DACA76-85-C-0008

Keywords: Scene Interpretation, Sensor Motion, Spatial Reasoning

This report presents the results of the project on Dynamic Image Interpretation for Autonomous Land Vehicle (ALV) Navigation for the time period 2/26/87 — 2/25/88. The purpose of the ALV project is to develop algorithms and tools to enable a vehicle to navigate autonomously through realistic landscapes.

The current effort continues our work on this problem. In the report we summarize the accomplishments of the past year in constructing robust algorithms to be used for vehicle navigation, as well as tools that have been developed to more efficiently utilize these algorithms.

ETL-0517 AD-A202 302

AUTOMATED FEATURE ATTRIBUTE ACCESSING FROM MAP TEXT
November 1988

Stephen F. Hasenfus

Keywords: Bar Codes, Optical Character Recognition, Feature Identifiers, Feature Attributes, Optical Scanning Devices

This report documents an investigation into the feasibility of placing machine-readable symbology (bar codes or OCR text) on map products. The approach to this research included a survey of optical-scanning devices, procurement of suitable devices, and interfacing the equipment to a personal computer for the development of a prototype automated feature attribute access system. This report documents the issues that surfaced during the design and testing of this prototype system.

ETL-0518 AD-A202 831

LASS-II RAPID GEODETIC SURVEY SYSTEM (RGSS)
April 1986

S. Wei, J. Eckenrode, R. Toler, J. Welch

Litton Guidance & Control Systems DACA72-84-C-0003

Keywords: Position and Azimuth Determining System, Litton Auto Surveyor System, Rapid Geodetic Survey System, Gravity Disturbance Vector, Gravity Anomaly

This final Technical Report presents the progress to date on the conversion of a standard U.S. Army Position and Azimuth Determining System (PADS AN/USQ-70) to a Litton Auto Surveyor System Dash II (LASS-II) to a Rapid Geodetic Survey System (RGSS). Multiple efforts have been initiated for this contract requirement as follows:

1. Perform the non-recurring Engineering design for conversion of a LASS-II to an RGSS.

2. Perform the necessary real-time software mechanization changes to enable an RGSS to attain the following performance goals:

   a. Interim Goal: Map the gravity disturbance vector to 0.3 sec (RMS) for the deflection components and 0.5 milligal (RMS) for the gravity anomaly.

   b. Long Term Goal: 0.1 sec (RMS) for the deflection component and 0 .1 milligal (RMS) for the gravity anomaly as the ultimate goal.

3. In depth investigation of RGSS real-time software definitions, output parameters expansion, and computer simulations for validation of the on-line software mechanization. Hardware changes, real-time software modifications and definitions are contained herein to attain the interim and ultimate performance goals. This final report discusses the software changes generated along with the hardware changes made to date. Although the hardware changes discussed herein are not necessarily the final configuration, the drawing package submitted under a separate CDRL line item will be definitive for permanent record of all hardware modifications initiated and finalized.

ETL-0519 AD-A207 596

VISION-BASED NAVIGATION FOR AUTONOMOUS GROUND VEHICLES
THIRD ANNUAL REPORT
November 1988

Larry S. Davis

University of Maryland

DACA76-84-C-0004

Keywords: Autonomous Navigation, Road Following, Computer Vision

This is the third annual report for DARPA sponsored ETL contract DACA76-84-C-0004 (DARPA Order 5096), covering the period July 1986 through July 1987. The report describes both new equipment added to our laboratory and the research performed on autonomous vehicle navigation. We describe the design of a structured light range scanner that has been built and mounted on our robot arm. This scanner provides us with the capability of generating range data similar to that obtainable on the Autonomous Land Vehicle (ALV) using the ERIM scanner. The report also describes the following research projects conducted during the past year:

1) The design and implementation of a rule-based road following system

2) Road obstacle detection in range data

3) Theoretical analysis of the accuracy of road recovery using motion stereo

4) Parallel vision on the Connection Machine

Finally, the report ends with a discussion of our plans for research during the next three years of our autonomous vehicle navigation research.

ETL-0520 AD-A212 806

SPATIAL DATA STRUCTURES FOR ROBOTIC VEHICLE ROUTE PLANNING
December 1988

Michael J. Black
David L. Milgram
Sharon O. Cioffi
Patrice Gelband

Advanced Decision Systems DACA72-87-C-0015

Keywords: Route Planning, Data Structures, Robotic Vehicles, Terrain Representations

This is the final report for the Phase II Small Business Innovative Research (SBIR) contract, "Spatial Data Structures for Robotic Vehicle Route Planning." The report describes the work completed during Phase II and discusses the directions for future research.

The goal of the Phase II SBIR contract was to investigate techniques and tradeoffs for representing digital terrain information in a computer environment. The long-term goal of this research is to build a Spatial Data Structure Development System (SDSDS) to serve as the infrastructure base for terrain analysis applications.

The Phase II contract addressed the following issues: 1) implementation of common terrain representations, 2) implementation of common spatial operations, 3) design of a methodology for evaluating the performance of spatial operations, 4) evaluation of the implemented representations and operations, and 5) initial design of testbed on which the SDSDS would be built.

ETL-0521 AD-B129 848L

KNOWLEDGE-BASED VISION TECHNIQUES
THIRD ANNUAL REPORT
December 1988

M. J. Daily
J. G. Harris
K. E. Olin
K. Reiser
D. Y. Tseng
F. M. Vilnrotter

Hughes Research Laboratories DACA76-85-C-0007

Keywords: Computer Vision, Virtual Sensors, Obstacle Detection, Obstacle Avoidance, Knowledge Representation

Efforts under the Knowledge-Based Vision Techniques contract have been concentrated on perception needs for autonomous land navigation, in particular obstacle detection and avoidance for off-road maneuvers. Major accomplishments have included: the formal definition of obstacles in terms of clearance, suspension, and slope using a three-dimensional vehicle model; techniques to use laser range and color sensor information; representing the sensed terrain by developing Cartesian Maps of sensed elevation, color information, and the fusion of both information sources; the fusion of information from multiple frames of a single sensor to build a composite map; and the development of an extensive simulation environment. These efforts culminated in the first cross-country map and sensor-based autonomous operation of a robotic vehicle in natural terrain. These experiments satisfied the milestones of the DARPA Technology Status Review for the Autonomous Land Vehicle (ALV) Program approximately one year ahead of schedule.

ETL-0522 AD-A208 546

RESEARCH IN KNOWLEDGE-BASED VISION TECHNIQUES FOR THE AUTONOMOUS LAND VEHICLE PROGRAM THIRD ANNUAL REPORT
December 1988

R. Nevatia
K. Price

University of Southern California DACA76-85-C-0009

Keywords: Autonomous Land Vehicle, Motion Analysis, Target Detection and Description, Knowledge-Based Vision

This report describes our research in motion analysis and estimation techniques for the period of June 1, 1987 to May 31, 1988. This research is of particular relevance to the DARPA Autonomous Land Vehicle (ALV) program, but should also be of other general utility. Our basic approach to detecting and tracking motion is to extract and match features, such as lines and regions, from a sequence and to generate motion estimates from these. We present one report on matching edge elements in connected line segments (contours) in a sequence of views. This work assumes relatively small motions between views.

We also present a report on an alternative representation for motion and a technique to use occlusion in spatio-temporal analysis. We also present results from a basic integrated system that combines feature extraction, matching and motion estimation.

ETL-0523 AD-A208 806

A SMART MAPPING, CHARTING AND GEODESY CONTROL GENERATOR PHASE II
December 1988

W. Kober
J. Curlander
M. Karspeck
F. Leberl

Vexcel Corporation DACA72-87-C-0011

Keywords: Automated Control Generation, Inertial Navigation System (INS), Image Registration, Global Positioning Satellite System (GPS)

The real-time automated registration of multi-sensor imagery begins with the generation of control information. A specific application may require the registration of newly acquired data to an existing spatial database (absolute registration), or to other images of a series (relative registration). This study examines the feasibility and upper-level design of a system capable of providing the control information required for a range of image registration tasks and image types. In general, the control generator we suggest will be guided by a spatial database maintaining information about the feature content of the area of interest. A rule-based query generator will extract candidate ground control optimized for the particular image type and geometry at hand.

ETL-0524 AD-A204 253

CONSENSUS THEORY IN EXPERT SYSTEMS: AN ADAPTIVE INFERENCE FRAMEWORK AND APPLICATION TO IMAGE UNDERSTANDING

December 1988

Kathryn B. Laskey
Paul K. Black
Marvin S. Cohen
James R. McIntyre
William G. Roman
Russell R. Vane, III

Decision Science Consortium, Inc.

DACA72-86-C-0003

Keywords: Expert Systems, Belief Functions, Non-Monotonic Logic, Assumption-Based Truth Maintenance, Image Understanding

Advances in automated image understanding technology are essential to our ability to exploit today's sophisticated imagery capabilities to support battlefield intelligence requirements. This report describes the application of a unique inference framework, Non-Monotonic Probabilist, to the problem of achieving consensus among modules, each of which supports a different part of the image understanding problem. Non-Monotonic Probabilist combines symbolic default reasoning with numerical uncertainty propagation to support a flexible ability to make and revise assumptions, to examine the degree of conflict associated with the current set of assumptions, and to resolve conflicts by "reaching inside" arguments and adjusting the underlying assumptions. Non-Monotonic Probabilist is a generic inference engine that is domain independent and can be applied to a variety of problems. Non-Monotonic Probabilist has been embedded within COMMiTR, a consensus system intended to be incorporated within the Expert Resolution System at the U.S. Army Engineer Topographic Laboratories.

ETL-0525 AD-B131 826L

KNOWLEDGE-BASED ANALYSIS OF SCENE DYNAMICS FOR TARGET MOTION DETECTION, RECOGNITION AND TRACKING
SECOND ANNUAL REPORT
January 1989

Bir Bhanu

Honeywell Systems and Research Center

DACA76-86-C-0017

Keywords: Strategic Computing, Qualitative Reasoning and Modeling, Motion Detection, Tracking, Landmark Recognition, Terrain Interpretation, Dynamic Modeling and Matching, Hierarchical Symbolic Grouping, Autonomous Land Vehicle, Dynamic Scene Understanding, Estimation of Vehicle Motion, Multispectral Images, Machine Learning, Knowledge Acquisition, Computer Vision

This is the Final Report of Honeywell's Contract on Knowledge-Based Analysis of Scene Dynamics for Target Motion Detection, Recognition, and Tracking prepared for the U.S. Army Engineer Topographic Laboratories (ETL) Contract DACA76-86-C-0017 and sponsored by the Defense Advanced Research Projects Agency (DARPA). Our research in Scene Dynamics and Object Recognition presented in this report is directed towards knowledge-based interpretation of scene dynamics and model-based object recognition. The results of our research make a significant technical contribution in vision-controlled navigation/guidance of Autonomous Land Vehicles (ALVs), reconnaissance, surveillance, and other practical military applications such as search and rescue and targeting missions. The topics investigated during the two year period of the contract are:

1) *Qualitative Reasoning & Modeling* for motion detection and tracking.
2) *Dynamic Model Matching* for landmark recognition.
3) *Digital Map Integration* for target tracking and landmark recognition.
4) *Automatic Model Acquisition and Refinement* using machine learning.
5) *Hierarchical Symbolic Grouping* for interpretation of terrain.

This synopsis of technical achievements in each of these areas is presented in the extended abstract in the report.

ETL-0527 AD-B136 480L

AN APPROACH TO MODEL FORMATION BASED ON FORMAL GEOMETRIC REASONING
SECOND ANNUAL REPORT
February 1989

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Nelson R. Corby
Deepak Kapur

General Electric Company

DACA76-86-C-0007

Keywords: Model Matching, Range Sensor, Image Understanding, Geometric Reasoning

Methods for model matching and model formation are developed in the context of polyhedral model-based image understanding. Our basic approach using a vertex-pair as a matchable, efficient polyhedral geometric feature has been extended by considering methods to automate the selection of features and verify hypothesized matches. A method to automatically select the most salient model features is described. The method uses an error metric which is stable and useful for evaluating feature quality.

Progress in automatic construction of matchable models using Boolean Intersection methods on multiple luminance views and in range data-based modeling is described. Geometric and algebraic reasoning methods for model formation and object recognition continues as a key focus. A significant problem was found to be selection of an appropriate symbolic parameterization. The nature of the representation determines the complexity of solution. Work continues on extending the two-dimensional geometric reasoning system, GEOMETER, developed in the past, to a three-dimensional system.

The vertex-pair approach is being applied to photointerpretation problems in PACE (Perceptual Analysis and Control Environment) which seeks to recognize targets from multiple images and produce an integrated representation in a common world frame of reference.

ETL-0528 AD-A209 132

PARALLEL VISION ALGORITHMS
SECOND ANNUAL TECHNICAL REPORT
January 1989

Hussein A. H. Ibrahim, Editor
John R. Kender
Lisa G. Brown

Columbia University DACA76-86-C-0024

Keywords: Computer Vision, Artificial Intelligence, Image Understanding, Multi-Resolution, Stereo, Texture, Strategy Computing

The "Parallel Vision Algorithms" second annual technical report covers the project activities during the period from October 1, 1987, through December 28, 1988. The objective of this project is to develop and implement, on highly parallel computers, vision algorithms that combine stereo, texture, and multi-resolution techniques for determining local surface orientation and depth. Such algorithms will immediately serve as front-ends for autonomous land vehicle navigation systems. During the second year of the project, efforts have concentrated on the following: first, implementing and testing on the Connection Machine the parallel programming environment that will be used to develop, implement and test our parallel vision algorithms. Second, implementing and testing multi-resolution stereo, and texture algorithms in this environment. Also, we continue our efforts for the refinement of techniques used in our texture algorithms. This report describes the status and progress of these efforts. We describe first the programming environment implementation, and how to use it. Then, we present algorithms and test results for multi-resolution stereo, and texture algorithms. More results of the efforts of integrating stereo and texture algorithms are presented.

ETL-0529 AD-A212 489

PARALLEL ALGORITHMS FOR COMPUTER VISION
THIRD YEAR REPORT
January 1989

Tomaso Poggio

Massachusetts Institute of Technology DACA76-85-C-0010

Keywords: Computer Vision, Parallel Algorithms and Architectures

This is the third annual report for Contract DACA76-85-C-0010, entitled "Parallel Algorithms for Computer Vision — Task B," sponsored by the Defense Advanced Research Projects Agency (DARPA), and administered by the U.S. Army Engineer Topographic Laboratories (ETL). The time period covered is the second year that we have had the Connection Machine (CM) available to us. During the same period of time, we successfully demonstrated the Vision Machine system processing images and recognizing objects through the integration of several visual cues. The first version of the Vision Machine system, which is based on the CM and uses an Eye-Head robot as an input device, is now complete and functional. In parallel with the development of the Vision Machine, we have also continued to study the performance of alternative, nonconventional architectures for navigation. The body of this report gives an overview of the results of our research during the third year of funding. Details can be found in the appendices of the report.

ETL-0530 AD-A205 195

LINEAR FEATURE EXTRACTION FROM RADAR IMAGERY: SBIR PHASE II, OPTION II
December 1988

David L. Milgram
Philip Kahn
Gary D. Conner
Daryl T. Lawton

Advanced Decision Systems DACA72-86-C-0004

Keywords: SAR, Feature Extraction, Edge Detection, Terrain Analysis, Image Understanding

The goal of this effort is to develop and demonstrate prototype processing capabilities for a knowledge-based system to automatically extract and analyze linear features from Synthetic Aperture Radar (SAR) imagery. This effort constitutes Phase II funding through the Defense Small Business Innovative Research (SBIR) Program. Previous work examined the feasibility of and technology issues involved in the development of an automated linear feature extraction system. This final report documents this examination and the technologies involved in automating this image understanding task. In particular, it reports on a major software delivery containing an image processing algorithmic base, a "perceptual structures" manipulation package, a preliminary hypothesis management framework, and an enhanced user interface.

ETL-0531 AD-A20[illegible] 696

TARGET LOCATION ERRORS DERIVED FROM A HYPOTHETICAL TARGET TRACKING SYSTEM
February 1989

Michael A. Crombie

Keywords: Real-Time Attitude, Real-Time Positioning, Real-Time Targeting

An error analysis of a hypothetical target tracking system developed around an ongoing real-time attitude (RTA) project at the Space Programs Laboratory was performed at the U.S. Army Engineer Topographic Laboratories. An extensive set of tables of target errors was developed as a function of a variety of collection geometries and system component random errors. The target tracking system includes RTA, a real-time positioning capability, an automatic target sensor, and a slant range measuring device. The system components were characterized in the study by their expected random errors. For example, the real-time positioning capability in this study reflects the expected range of GPS errors.

ETL-0532 AD-A206 950

SPATIAL TARGET LOCATION ERRORS DERIVED FROM MEASUREMENTS COLLECTED FROM SIXTEEN SATELLITE CONSTELLATIONS
March 1989

Michael A. Crombie

Keywords: Satellite Constellations, Minimum PDOP Values, Shortest Distance to Target

In this report, tables of sample cumulative probability distributions of minimum PDOP (Position Dilution of Precision) values and shortest distances between target and target trackers were developed, where the target is a spatial one and where the target trackers are constrained to any one of 16 satellite constellations. Shortest distance was used as a parameter in this work because target location errors involving direction to target increase as distance to target increases. The tables pertain to the first, second, and third shortest distances and to minimum PDOP's computed from slant range observations taken from 3, 4, or 5 target trackers. Tables of expected values of minimum PDOP's and shortest distances are also provided. Values in the tables of shortest distances are also provided. Values in the tables of shortest distances can be combined with a prior error analysis to determine 99 percent confidence sphere radii about estimated target locations. Values in the tables of minimum PDOP's can be used to determine 99 percent confidence sphere radii about target locations estimated from 3, 4, or 5 slant range observations.

ETL-0533 AD-B132 885L

AUTOMATIC RADAR FEATURE EXTRACTION SYSTEM USING DESCRIPTORS
March 1989

Daniel K. Gordon
Paul W. Mueller

Autometric, Incorporated DACA76-88-C-0005

Keywords: Computer Vision, SAR Imagery, Descriptor Sets, Automatic Feature Extraction, Expert Systems

The research investigation described in this interim report identified and developed image processing and computer vision techniques used for suppressing noise and for enhancing and automatically identifying features of interest in SAR imagery. This project built upon computer vision software already developed during the previous phase. Under the previous phase, software was developed that automatically identified line drawings of SAR feature descriptor sets that were identified during the initial phases of the investigation.

ETL-0534 AD-A207 361

EXPERT SYSTEM FOR MINEFIELD SITE PREDICTION PHASE II FINAL REPORT May 1989

Jonathan W. Doughty
Anne L. Downs

PAR Government Systems Corporation DACA72-86-C-0017

Keywords: Expert System, Minefield Site Prediction, GIS (Geographic Information System), Quadtree, Window System, Terrain Analysis, Minefield Doctrine

This report reviews the major system components of the MSPES and discusses modifications made to the system under Phase II of this contract. Phase II development grew out of the prototype system developed under Phase I. A high-level description of the software architecture was presented in an earlier document (Barth et al., 1987), with a more detailed description presented in the Phase I Final Report (Dillencourt et al., 1988). The scope of Phase II was the development of a "complete expert system for minefield site prediction." Phase II MSPES development continued on the Sun 3/160 at the request of ETL. The transporting of the system to the target computer, a VAXStation II GPX, was scheduled for Phase III. Phase II effort was concentrated in two areas: first, the implementation of the user interface using the X Window System graphics package, and secondly, in expanding the knowledge base of minefield doctrine.

ETL-0535 AD-B132 407L

KNOWLEDGE-BASED VISION TECHNIQUES TASK B: TERRAIN AND OBJECT MODELING RECOGNITION THIRD ANNUAL REPORT April 1989

Advanced Decision Systems:

Daryl T. Lawton	Patrice Gelband
Tod S. Levitt	John W. Dye
Christopher C. McConnell	Philip Kahn
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Advanced Decision Systems DACA76-85-C-0005

Keywords: Model-Based Vision System, Terrain Modeling, Schema-Based Reasoning, Perceptual Processing, Image Understanding Tools, Spatial Representation, Hypothesis Management, Navigation, Image-To-Map Matching

This report describes the development and critical components of a model-based vision system for an autonomous vehicle operating in complex, outdoor, dynamic environments using optical, laser, motion, and position sensors. The critical technologies are organized with respect to Object and Event Modeling, Perceptual Processing, Spatial Representation and Reasoning, and the Integration of work in these research areas into modular and transferable components. Key results included the following: (Editor's note: results can be seen on original DD Form 1473 in the published report).

ETL-0536 AD-B133 660L

KNOWLEDGE-BASED VISION TECHNIQUES: OBSTACLE DETECTION AND AVOIDANCE FOURTH ANNUAL REPORT May 1989

K. E. Olin
M. J. Daily
M. D. Howard
F. M. Vilnrotter
D. Y. Tseng

Hughes Research Laboratories

DACA76-85-C-0007

Keywords: Computer Vision, Obstacle Detection, Knowledge Representation, Virtual Sensors, Obstacle Avoidance, Cross Country Navigation

Efforts under the Knowledge-Based Vision Techniques contract have been concentrated on perception needs for autonomous land navigation, in particular obstacle detection and avoidance for off-road maneuvers. Major accomplishments have included: the formal definition of obstacles in terms of clearance, suspension, and slope using a three-dimensional vehicle model; techniques to use laser range and color sensor information; representation of sensed terrain by developing Cartesian maps of elevation, color, data fused from both sensors, and data representing traversability weights; the fusion of information from sequences of laser range data to both build a composite map of a vehicle path and to compare sensed data with data obtained from digital maps; and the development of an extensive simulation environment. These efforts demonstrated the first cross-country map and sensor-based autonomous operation of a robotic vehicle in complex natural terrain. These experiments, on-board the Martin Marietta Autonomous Land Vehicle (ALV), satisfied the DARPA Technology Status Review (TSR) milestone for cross-country navigation approximately one year ahead of schedule.

ETL-0537 AD-A210 594

1988 YEAR END REPORT FOR ROAD FOLLOWING AT CARNEGIE-MELLON
May 1989

Charles E. Thorpe
Takeo Kanade

Carnegie-Mellon University DACA76-85-C-0003

Keywords: Road Following, Range Data Interpretation, Expert Systems for Image Interpretation, Car Recognition, Geometric Camera Calibration

This report describes progress in vision and navigation for outdoor mobile robots at the Carnegie-Mellon Robotics Institute from January 1988 through March 1989. This research was primarily sponsored by the Defense Advanced Research Projects Agency (DARPA) as part of the Strategic Computing Initiative. Portions of this research were also partially supported by the National Science Foundation and Digital Equipment Corporation. In the four years of the project, we have built perception modules for following roads, detecting obstacles, mapping terrain, and recognizing objects. Together with our sister contract, "Development of an Integrated ALV (Autonomous Land Vehicle) System," we have built systems that drive mobile robots along roads and cross country, and have gained valuable insights into viable approaches for outdoor mobile robot research. This work is briefly summarized in Chapter 1 of this report. Specifically in 1988 and the first three months of 1989, we have completed one color vision system for finding roads, begun two others that handle difficult lighting and structured public roads and highways, and built a road-following system that uses active scanning with a laser rangefinder. We have used 3-D information to build elevation maps for cross-country path planning, and have used maps to retraverse a route. Progress on these projects is described briefly in Chapter 1, and in more detail in the remaining chapters.

ETL-0538 AD-A209 523

GROUND TARGET LOCATION ERRORS DERIVED FROM MEASUREMENTS COLLECTED FROM A VARIETY OF HYPOTHETICAL SATELLITE SENTINEL SYSTEMS
June 1989

Michael A. Crombie

Keywords: Satellite Constellations, Target Location, Stellar Camera, Real Time Attitude

A large number of symmetric circular orbit satellite constellations were tested for their worth in providing continuous surveillance of five selected corps-sized regions over various parts of the world. The results of this work when combined with results from a previous report can be used to evaluate the target location mensuration capability of a variety of target mensuration systems located on satellite platforms defined by the constellations.

ETL-0539 AD-B135 161L

AUTONOMOUS LAND VEHICLE (ALV) PLANNING AND NAVIGATION SYSTEM FINAL ANNUAL REPORT May 1989

D. Keirsey
D. Payton
J. Rosenblatt
D. Y. Tseng

Hughes Research Laboratories DACA76-85-C-0017

Keywords: Mobile Robots, Autonomous Vehicles, Planning, Navigation

This report summarizes some of the first cross-country navigation experiments performed on the Defense Advanced Research Projects Agency (DARPA) Autonomous Land Vehicle (ALV) and describes in detail the planning software architecture that has been developed as a result of experience gained from these experiments. We present a set of architectural concepts which address the needs for integrating high-level planning activities with lower-level reactive or participatory behaviors. Based on lessons learned from experience with our hierarchical architecture for autonomous cross-country navigation, we have adopted a new approach which emphasizes the minimization of information loss both within and between system layers. The resulting change in perspective has allowed us to greatly enhance the overall capabilities and performance of our system.

ETL-0540 AD-A212 622

AN ANALYSIS OF AIR PHOTO AND RADAR IMAGERY OF BARRO COLORADO ISLAND, PANAMA July 1989

J. N. Rinker
P. A. Corl

Keywords: Air Photo Analysis, Radar Analysis, Closed Tree Canopy, Tropical Landforms

Imagery of terrain that is covered with a closed canopy of tall trees does not show the ground surface, and any information about surface characteristics, such as rock and soil types, structure, drainageways, etc., must come from an examination of the tree canopy surface. An evaluation of stereo aerial photography showed that inferences could be made about general terrain characteristics such as landform, probable structure and rock types, and major drainageways, but it requires experienced and skilled analysts, and stereo imagery. Surface roughness, obstacles, and minor drainageways could not be determined. Lack of vegetation penetration by radar severely limits the quantity and quality of information that can be derived.

ETL-0541 AD-A212 490

PARALLEL VISION ALGORITHM DESIGN AND IMPLEMENTATION
1988 END OF YEAR REPORT
August 1989

Carnegie-Mellon University DACA76-85-C-0002

Takeo Kanade
Jon Adrian Webb

Keywords: Computer Vision, Systolic Processors, Benchmarks, Programming Languages, Parallel Computers, Warp, Image Processing

The Apply programming language has been extended to allow variable-sized image computations, and also to allow border mirroring, in which pixels accessed outside the borders are produced by copying pixels from the interior of the image. Implementation and design decisions are discussed. Apply and the WARP programming language W2 were used to implement the second DARPA image understanding benchmark. The results of this implementation are reported. Experience with this benchmark suggests a method for performing global image computations in a machine independent manner, using the divide and conquer model. Implications of this model for algorithms in the image understanding benchmark are discussed. It is shown that this model is capable of computing any algorithm in which data is accessed in a fixed order, regardless of the data values, and in which the final computation is reversible: that is, it produces the same results if the data values are reversed in order.

ETL-0542 AD-A212 621

THE IMAGE UNDERSTANDING ARCHITECTURE PROJECT SECOND ANNUAL REPORT March 1989

Charles C. Weems
Steven P. Levitan
Allen R. Hanson
Edward M. Riseman
David B. Shu
J. Gregory Nash
James Burrill
Michael Rudenko

University of Massachusetts

DACA76-86-C-0015

Keywords: Image Understanding Architecture, Knowlege-Based Vision, Real-Time Computer Vision, Software Simulator, Parallel Processor

The primary goal of the Image Understanding Architecture (IUA) project is to build a proof-of-concept prototype of a 1/64th slice of a next generation vision architecture, and develop the software support environment that will be needed to utilize the hardware. The majority of the hardware effort is taking place at Hughes Research Laboratories, Malibu, California, although UMass has principal responsibility for the design of the IUA architecture. UMass has also undertaken some smaller portions of the hardware development (the feedback concentrator for the low and intermediate level arrays, and the communications router for the intermediate level array). The majority of the software effort is taking place at UMass, although Hughes is also involved in some software development, both in support of their hardware efforts, and in the form of algorithm development for specific applications on the IUA. During the second year of this program, we have focussed on extensions to the IUA software simulator programming environment, the development of library routines and demonstration software for the IUA, construction of the custom chips for the architecture, circuit board design, and the design and implementation of an integrated image understanding benchmark for DARPA. This report presents the results of the IUA project for the second year of its original two-year contract period. The purpose of the IUA project is to design and construct a next-generation parallel processor that specifically addresses the needs of real-time computer vision applications. Included in this report is a summary of accomplishments during the second year, an overview of the IUA design, a description of the new DARPA Integrated IU Benchmark Exercise, a summary of the performance figures for the IUA on the exercise, and test reports and photos of chips developed through MOSIS under this program in an appendix.

ETL-0543 AD-A211 584

VISION-BASED NAVIGATION FOR AUTONOMOUS GROUND VEHICLES SUMMARY REPORT August 1989

Larry S. Davis

University of Maryland

DACA76-84-C-0004

Keywords: Autonomous Navigation, Road Following, Computer Vision

This is a summary report for contract DACA76-84-C-0004, "Vision-Based Navigation for Autonomous Ground Vehicles." Our research has resulted in seventeen technical reports (list appended to this report, with abstracts), many of which have been subsequently published in journals, conferences and workshops. Additionally, our project involved close collaboration with the Martin Marietta Corporation, Denver, Colorado, in the development and testing of vision algorithms for navigation of roads and road networks. Several experiments were run on the Martin Marietta Autonomous Land Vehicle using programs developed at the University of Maryland, and some critical components of Martin Marietta's visual navigation system were based on fundamental research conducted at the University of Maryland under support of this contract — specifically, the overall framework of a focus-of-attention vision system, in which detailed analyses are performed on selected windows of images of roads, and the shape-from-contour algorithms (e.g., the zero-bank algorithm) that allowed the vehicle software to recover an accurate three-dimensional road model from monocular imagery, thus saving the autonomous land vehicle (ALV) from having to perform costly, and less reliable, analyses based on either stereo or motion.

ETL-0544 AD-A211 876

SENTINEL SATELLITE POSITIONAL PRECISION DERIVED FROM THE NAVSTAR GLOBAL POSITIONING SYSTEM August 1989

Michael A. Crombie

Keywords: Global Positioning System (GPS), Position Dilution of Precision (PDOP), Satellite Position Precision

Error estimates of position are presented for a variety of symmetric circular satellite constellations when four or five observations are made on NAVSTAR GPS satellites. Results are calculated in terms of minimum PDOP and expected outages.

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APPENDIX – TITLES

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TITLE	REPORT NO.	YEAR
Accuracy of Cartometric Data	AD 810 496	1966
Accurate Emphemeris Time Determination and Geocentric Stations Position from Photographs of the Moon Against Stellar Background	ETL-RN-72-4	1972
Acousto-Optic Technology for Topographic Feature Extraction and Image Analysis	ETL-0256	1981
Acquisition and Evaluation of Thermal Standard Data	ETL-0218	1980
Adjunct Development Test II (DT II) of Position and Azimuth Determining System AN/USQ-70	ETL-0217	1980
Advanced Continuous Tone Plate and Process Compatible with Present Military Lithographic Reproduction Equipment and Practices	ETL-0056	1975
Advanced Edit System	ETL-0295	1983
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Advanced Feature Symbolization for Three Dimensional Views	ETL-0223	1980
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Advanced Radar Topographic Application	ETL-CR-73-2	1973
Advanced Satellite Hardware/Software System Study	ETL-0225	1980
Advanced Satellite Tracking Instrumentation Study	AD 882 2546	1968
Advanced Study of a Position and Azimuth Determining System (Final)	AD 844 930L	1968
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Analysis and Tests of Environmental Effects on Gyrocompassing Accuracy	ETL-0378	1984
Analysis of a Relaxation Scheme to Improve Terrain Elevation Data, An	ETL-0298	1982
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Analysis of SECOR Data — Vol. I	AD 865 488L	1968
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Circumpolar Method for Determining Azimuth	ETL-0317	1983
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Classification of Metamorphic Rocks and Their Applications to Air Photo Interpretation Procedures, The	ETL-0341	1983
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Color Ink-Jet Demonstration Program	ETL-0196	1979
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Combined Engineering and Service Tests of the Map Revision Van Section of the Motorized Photomapping Train	1447-TR	1956
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Comprehensive Summary of Project Trend	ETL-0041	1975
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Cultural Data Base Implementation Study and Computer-Aided Scene Modeling System Users Manual	ETL-0380	1984
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Design and Development of Power Package for Surveying Instrument: Azimuth, Gyro, Lightweight	ETL-CR-71-5A	1971
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TITLE	REPORT NO.	YEAR
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TITLE	REPORT NO.	YEAR
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Interactive Digital Image Processing for Terrain Data Extraction	ETL-0241	1980
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Inverse Perspective of a Road from a Single Image	ETL-0429	1986
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TITLE	REPORT NO.	YEAR
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